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FIRE TESTS OF LOAD BEARING STEEL STUD WALLS EXPOSED TO REAL BUILDING FIRES

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Abstract. *Fire resistance has become an important part in structural design due to the ever increasing loss of properties and lives every year. Conventionally the fire rating of load bearing Light gauge Steel Frame (LSF) walls is determined using standard fire tests based on the time-temperature curve given in ISO 834 [1]. Full scale fire testing based on this standard time-temperature curve originated from the application of wood burning furnaces in the early 1900s and it is questionable whether it truly represents the fuel loads in modern buildings. Hence a detailed fire research study into the performance of LSF walls was undertaken using real design fires based on Eurocode parametric curves [2] and Barnett's 'BFD' curves [3]. This paper presents the development of these real fire curves and the results of full scale experimental study into the structural and fire behaviour of load bearing LSF stud wall systems.*

1 INTRODUCTION

In recent times, LSF stud wall systems are extensively used in residential, industrial and commercial buildings as primary load bearing components. Although they have been used widely, their behaviour in real fires is not fully understood, especially in relation to fire resistance. The fire resistance of LSF stud walls has been traditionally determined using the standard fire tests specified in ISO 834 [1]. Fire Resistance Rating (FRR) should be sufficient in a fire event, for safe evacuation, fire service intervention and for rescue activities. Recent researches [4-6] have shown that the actual FRR of building elements exposed to real building fires is significantly less than that obtained from standard fire tests. Based on a series of Cardington fire tests, Lennon and Moore [4] suggested that the standard fire exposure would severely underestimate the severity of the fire in terms of maximum temperature and duration. Jones [5] has also shown that the actual fire resistance of building elements exposed to real building fires can be significantly less than the FRR obtained from exposing them to standard time-temperature curve [1].

Fire testing of LSF wall systems is generally based on the standard time-temperature curve given in ISO 834 [1], which originated based on wood burning. In reality, modern residential and commercial buildings also incorporate synthetic foams, fabrics and thermoplastic materials. Bwalya et al.'s [7] recent fire load survey of Canadian residential dwellings showed that although the cellulosic material takes up the highest contribution, plastics occupy 13 to 39% by weight and contribute 20 to 48% to the fuel load. This shows a significant contribution from synthetic plastic materials to the fire loads in residential dwellings. During a fire, these thermoplastic materials melt and flow to the floor and burn faster with higher heat release rates resulting in more severe fires than standard fires. Therefore building structural elements may not ensure safe evacuation, or offer the required life safety for occupants and fire rescuers.

The experimental time-temperature curve should cover most of the potential fires in buildings. However, the present standard time-temperature curve [1] may not meet this requirement. This was shown by many researchers [4-6] using compartment tests, where the maximum temperature of a natural fire exceeded the standard ISO curve within a short period of time from ignition. Also the shape of the curve strongly relates to the behaviour of an element during a fire. The natural building fire has a decay phase, whereas the ISO curve [1] rises continuously. This may be conservative for long duration, average temperature rise fires, but not for short duration, very hot fires. Also there is some concern nowadays about the importance of the behaviour of structural elements in the decay (cooling) phase of a building fire. Guo and Bailey [8] showed that significant structural damage can occur during the cooling phase. Standard fire tests will give good comparative results for building systems tested under identical conditions, and also valuable basic data, but do not provide accurate FRR for buildings which have a high fire severity. In a real fire, the growth, fully developed burning and decay phases depend on aspects such as the total fuel load present in the room, fuel type and configuration, ventilation openings and thermal properties of compartment lining materials. To overcome the current limitations in fire resistance of LSF walls, a research project is currently under way at the Queensland University of Technology (QUT). The main objective of this project is to undertake both experimental and numerical studies of LSF stud wall systems to develop a better understanding of the behaviour of these wall panels under realistic fire conditions. This paper presents the details of the development of realistic fire curves based on Eurocode parametric curves [2] and Barnett's 'BFD' curves [3] and the results of full scale fire tests of five LSF stud wall systems. The test variables included fire scenario, LSF wall panels and load ratio.

2 NON-STANDARD DESIGN FIRES

Fire behaviour prediction models representing the behaviour of a fire are of two types; pre-flashover and post-flashover models. The post-flashover fire scenario models are important in the analysis and design of the building fire safety systems whereas the pre-flashover fires mainly focus on the life safety of building occupants, especially the toxic gas production and fire spread. Several equations and computer models have been developed by researchers [3,9,10,15,16] to simulate the post-flashover time-temperature profiles. These fire profiles can be either probabilistic or deterministic models. The probabilistic models are based on previously captured compartment and real fire events while deterministic models utilise scientific principles to predict the fire behaviour with time. The fire profiles were obtained and validated for different types of fuels and ventilation conditions. Also most of the fire profile equations have limitations in-built within them and their range of application is limited and needs extensive calculations to derive a suitable time-temperature profile. For computer models more reliable and detailed measurement data from large-scale fire tests are needed for validation. Hence it is very difficult to envisage the time-temperature profile of a compartment fire. Also it is clear that a predefined standard fire curve in [1] to suit the real building fires is unrealistic and the design fires have to be determined based on the fuel load, ventilation openings and thermal properties of wall lining materials in a compartment. Therefore in order to investigate the structural and thermal behaviour of LSF wall panels under real building fire conditions, the time-temperature profiles recommended in Eurocode 1 Part 1-2 [2] known as the parametric curve and Barnett's 'BFD' [3] curve were selected.

Eurocode parametric curve allows a time-temperature relationship to be developed for a combination of the above mentioned parameters. The rate of temperature rise and peak temperatures in the Eurocode parametric curves are well above those in the ISO fire curve [1] in most situations for the same time period. But the decay rates are linear and very fast, leading to shorter fire durations. Pope and Bailey [11] also states that Eurocode parametric curve under-predicts the temperatures in the decay phase and the linear time-temperature relationship in the decay phase is not acceptable. Barnett [3] on the other hand states that the parametric curves are unrealistic as they do not take the shape of a fully developed fire, and recommends that the 'BFD' curve is much closer to the real fire time-temperature distribution. Barnett's 'BFD' [3] curve uses a single log-normal equation to represent both the growth and decay phases of a fire and has been developed using curve fitting to a wide range of experimental test results (142 natural fire tests with a range of fuels and different enclosure materials). The 'BFD Curve' is a good replacement for the standard time-temperature curve as it takes the shape of the natural fire curve and fits the results of actual fire tests closer than other methods. It requires only three factors; the maximum gas temperature, the time at which it occurred and a shape constant. Hence in order to study the structural and thermal behaviour of LSF walls under natural decay phase of a fire, Barnett's 'BFD' curve is also considered.

3 DEVELOPMENT OF REAL BUILDING DESIGN FIRES

As mentioned earlier, design fires are determined based on three parameters, namely; fuel load, ventilation openings and thermal properties of wall lining materials. Of these the fuel load density values depend on geographic locations, type of building and room use. Many varying values have been recommended by researchers and in codes of practice. It is uncertain which mean value and the percentile are to be selected in determining the time-temperature fire curve representing a more realistic fire scenario for residential buildings. Hence this question was raised with many academics, researchers and experts in the field of fire engineering, whose common recommendations and suggestion are to select a realistic value from the available literature that is justifiable to the present building environment than using a value obtained 20 years ago. Also there is no definitive value for a type of building and the fuel load density value alone does not provide a realistic time-temperature curve. Instead parameters such as composition of fuel load and heat release rates are also important in obtaining a more accurate curve together with ventilation opening sizes and thermal properties of wall lining materials. However for design purposes it is obvious to select the worst case fire scenario, which reflects the actual fire growth in a modern building. Therefore an average value of 780 MJ/m^2 was selected from Eurocode 1 Part 1-2 [2], which is very close to the Bwalya et al.'s [7] recent survey results (807 MJ/m^2) obtained for Canadian residential buildings. As recommended by most researchers, an 80th percentile value of 948 MJ/m^2 was selected for design purposes. Hence the design variable fuel load density based on floor area for residential building is 1138 MJ/m^2, taking in to account the combustion (m = 0.8), fire activation risks for compartment area (δ_1 = 1.5) and type of occupancy (δ_2 = 1) given in Eurocode 1 Part 1.2 [2].

Design fuel load density in a room is primarily made up of both permanent and variable fuel loads. Permanent fuel loads includes built-in combustible materials such as wall and floor finishes and other permanently installed equipment. The National Fire Protection Association (NFPA) in its NFPA 557 [12] has proposed a value of 130 MJ/m^2 for permanent fuel load density in buildings with non-combustible construction. Hence the design fuel load density for residential buildings is determined as 1268 MJ/m^2.

The compartment boundary of enclosure materials for this research is chosen to be with light gauge steel partitions lined with gypsum plasterboards and rock fibre insulations for walls and ceiling, and with concrete floor slab to represent a typical single storey residential building. The thermal inertia (*b*) for the compartment enclosure materials was calculated using Equation 1 as given in Eurocode 1 Part 1.2 [2].

$$b = \sqrt{\rho c \lambda} \qquad [\, J / m^2 s^{1/2} K \,] \tag{1}$$

Properties of 16 mm thick Firestop$^{(R)}$ Gypsum plasterboard at ambient (20^{o}C) temperature (Firestop$^{(R)}$ manufactured by Boral Plasterboards, Australia) are: Density (ρ) – 729 kg/m^3, Specific heat (c) – 950 J/kgK and Thermal conductivity (λ) - 0.25 W/mK. These values were recommended by Keerthan and Mahendran [13] based on their experimental and numerical studies of gypsum plasterboards, which led to a value (b) of 416 J/m^{2}s$^{1/2}$K. The values of 'b' for rock fibre insulation and concrete floor are 145 J/m^{2}s$^{1/2}$K) [13] and (b = 1899 J/m^{2}s$^{1/2}$K) [14], respectively. To account for different fire scenarios, two different fire compartments having light gauge steel frame walls and ceiling panels with and without rock fibre insulations and concrete floor were selected in this research, where Compartment – A walls and ceilings are lined with gypsum plasterboards and Compartment – B consists of rock fibre insulation sandwiched between these two plasterboards. Based on the 'b' values above, the compartment thermal inertia for enclosure surface with different layers of materials was calculated using the equations given in Eurocode 1 Part 1.2 [2]. Table 1 shows the values used to develop the design real fire curves namely: fuel load density ($q_{f.d}$), ventilation factor (O) and thermal inertia (b) of the compartment. The compartment geometry considered was based on the dimensions of 3600 (L) x 2400 (W) x 2400 (H) mm. Opening factors 0.08 and 0.03 m$^{1/2}$ were chosen to represent a rapid fire and a long-drawn-out fire for LSF walls.

Using these parameters three Eurocode parametric curves [2] were developed as shown in Figure 1. Fire curves EU1-(0.08) and EU2-(0.03) were considered to be the most appropriate curves as they represent a rapid fire (EU1) and a prolonged fire (EU2), respectively. They also come within the acceptable fire durations of about 60 minutes and 4 hours, respectively, for experimental purposes.

Table 1. Fire compartment characteristics

Design Parameters	Compartment - A		Compartment - B
Opening factor - O ($m^{1/2}$)	0.08	0.03	0.03
Design fuel load density - $q_{f.d}$ (MJ/m^2)	1268	1268	1268
Compartment Thermal Inertia - b ($J/m^2s^{1/2}K$)	715	702	585

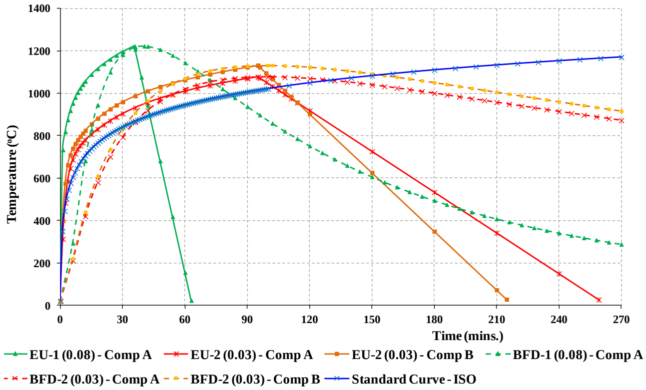


Figure 1. Real design fire time-temperature curves.

The 'BFD' curves [3] were also drawn for the same parameters as for the Eurocode parametric curves. In comparison, the peak temperature values of Barnett's [3] BFD curve are much less, but the shape of the curve fits well with the natural fire curve. The 'BFD' curve [3] calculates the maximum temperature from the equation recommended by Law [9] based on many experimental fires. This equation may not incorporate the modern materials such as thermoplastics and synthetic foams. Therefore it was decided to use the maximum temperature of the Eurocode parametric curve [2] for the 'BFD' curve. In developing the 'BFD' curves for opening factors 0.03 and 0.08 $m^{1/2}$, the time to reach the maximum temperature (t_m) was obtained from the Eurocode parametric curve equations as prescribed by the authors of the 'BFD' curve [15]. The Eurocode parametric curve does not include the pre-flashover phase and the time to reach the maximum temperature in Eurocode [2] (t_{max}) excludes the pre-flashover phase. However, 'BFD' curve [3] is a natural fire curve, which incorporates both pre-flashover and post-flashover phases. Hence the time to flashover point has to be added to t_{max} (Eurocode) to obtain t_m (BFD). The time to flashover was calculated based on Walton and Thomas's [16] expression for the critical value of heat release rate and fire growth rates specified in ISO 834 [1]. This way of modifying the original 'BFD' curves appears to be a reasonable solution to derive more realistic time-temperature curves for design. The 'modified BFD' curves and the Eurocode parametric curves [2] are shown in Figure 1.

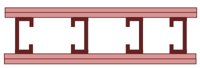
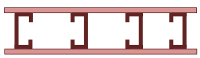
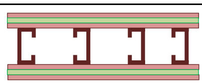
4 EXPERIMENTAL STUDIES

4.1 Test specimens

Test program consisted of fire tests of five LSF stud wall panels of 2100 mm width and 2400 mm height (LSF1 to LSF5). The wall panels consisted of four cold-formed steel lipped channel sections (90 x 40 x 15 x 1.15 mm) spaced at 600 mm and tracks (top and bottom) made of channel sections (92 x 50 x

1.15 mm). They were fabricated from 1.15 mm galvanized steel sheets with a minimum yield strength of 500 MPa. Test specimens LSF1 and LSF2 were lined with two layers of 16 mm thickness Firestop(R) gypsum plasterboards on either side of the studs. The first (base) layer of plasterboard consist of three pieces (150 x 2400, 1200 x 2400 and 750 x 2400 mm) to accommodate two vertical joints in Studs 1 and 3 (Figure 2). The second (face) layer where exists has two equal pieces (2100 x 1200 mm) fixed horizontally. Test specimens LSF3 and LSF4 were lined with single layer of plasterboard (16 mm thick) and LSF5 was built with 25 mm rock fibre insulation sandwiched between two 16 mm plasterboards on both sides of the steel frame. Table 2 gives the details of the load bearing LSF stud wall test specimens.

Table 2. Details of test specimen configurations.

Test	LSF Wall Configuration	Fire Profile	Load Ratio	Insulation Type
LSF1		EU2-(0.03) - Comp A	0.2 (15 kN/Stud)	-
LSF2		BFD2-(0.03) - Comp A	0.2 (15 kN/Stud)	-
LSF3		EU1-(0.08) - Comp A	0.2 (15 kN/Stud)	-
LSF4		BFD1-(0.08) - Comp A	0.2 (15 kN/Stud)	-
LSF5		BFD2-(0.03) - Comp B	0.4 (30 kN/Stud)	Rock fibre

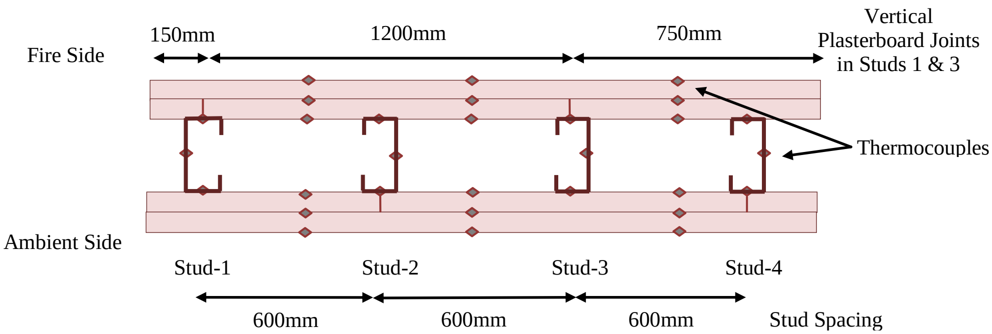


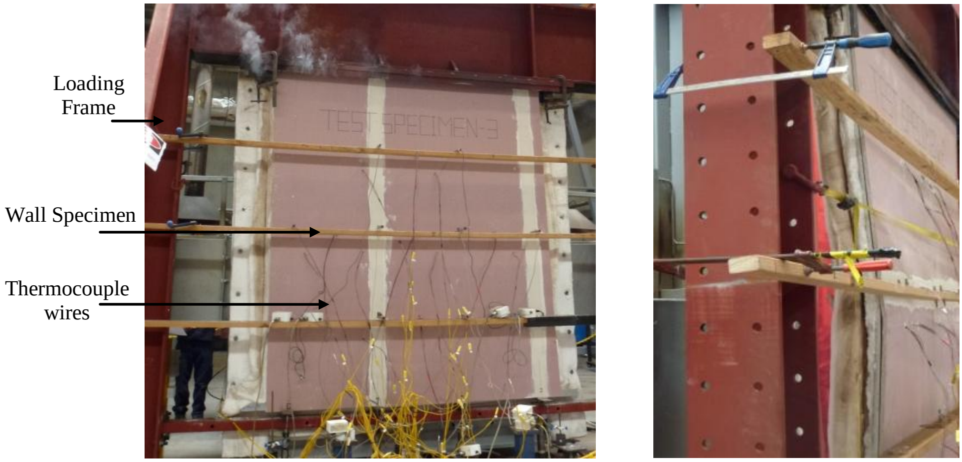
Figure 2. Typical arrangement of thermocouples for LSF wall specimen.

D-Type self drilling 16 mm long flat head screws were used to fix the studs to top and bottom tracks. Also D-Type self drilling 25 and 45 mm long bugle head screws were used to fix the first and second layers of plasterboards. The first plasterboard was screwed at 200 mm spacing along the edge studs where plasterboard joints exist and 300 mm spacing along the intermediate studs. S-Type 75 mm long bugle head screws at 300 mm centres were used to fix the second plasterboard for the insulation sandwiched wall panels. The plasterboard joints were sealed with two coats of plaster-based jointing compound and 50 mm wide paper type joint tape. Type-K cable thermocouples were used to measure the temperature development in the wall specimens. The stud and plasterboard surface temperatures were measured at three levels; 0.25H, 0.5H and 0.75H along the stud, where 'H' is the height of the wall panel of 2400 mm (Figure 2). The thermocouple wires on the studs were connected to their hot and cold flanges and web.

4.2 Test set-up and procedure

Fire tests on LSF stud wall systems were conducted using the propane gas furnace. Four thermocouples monitor the furnace temperatures in the fire chamber during the fire test. These temperatures were used to control the fuel and air supply to the chamber to obtain the required time-temperature fire curve. The test specimen was placed in the loading frame, where the bottom track rested on the loading plates and the top track was clamped to the loading frame. The test specimen was placed to align the centroids of the studs with those of the loading plates and hydraulic ramps. Each loading plate was connected to individual hydraulic ramps and a single pump was used to apply the required axial load. A pressure transducer was connected to the hydraulic pump to record the applied pressure (load).

An axial compression load of 15 kN was applied to each stud in Test Specimens LSF1 – LSF4 by the hydraulic pump. The load was based on 0.2 times the ultimate capacity of each stud at ambient temperature obtained by Kolarkar [17], ie. load ratio of 0.2. An axial load of 30 kN (load ratio = 0.4) was applied to LSF5. These loads were applied at the room temperature and maintained during the fire test. The axial shortening of each stud and the out-of-plane movements of the wall specimen at 600, 1200 and 1800 mm heights were measured using displacement transducers. During the fire test the temperatures and displacements were recorded at 10 s intervals using a Labview data logger (Figure 3).



a. LSF wall during testing. b. Lateral deflection away from the furnace.

Figure 3. Fire testing of LSF wall specimen.

4.3 Results and Discussions

The proposed real design fire curves in Figure 1 were achieved reasonably well (within 50ºC) in all the tests as shown in Figures 4b, 5b and 6 except in Test LSF4 (within 100ºC). The structural failure of studs occurred instead of insulation or integrity failure in all the tests except Test specimen LSF1 that did not fail. In all the tests, the stud that had the vertical small strip of plasterboard (150 x 2400 mm) joint (Stud 1) was subjected to more heat flow due to the opening up of joints, except in LSF2 Stud 2. In specimen LSF2, a partial collapse of plasterboard attached to Studs 1 and 2 initiated the failure. Table 3 compares the failure times and critical stud temperatures when the Eurocode parametric and ‘BFD’ curves were used together with the results from the standard fire tests performed by Kolarkar [17] and Gunalan [18].

Gunalan’s [18] numerical studies for different LSF wall configurations showed that the stud failure is merely dependent on its hot flange temperature and not on its configuration. The effect of using different type of insulations and arrangement is simply to delay the time to reach that critical hot flange temperature in the LSF wall stud. These critical stud hot flange (HF) temperatures proposed by Gunalan [18] are also given in Table 3. The failure times shown in Table 3 were based on the time when the oil pressure in the hydraulic ramps could not be conserved, ie. the initial point of a rapid unloading phase noticed in the data logger. The stud hot flange (HF) temperature at this failure time was recorded as the critical HF temperature.

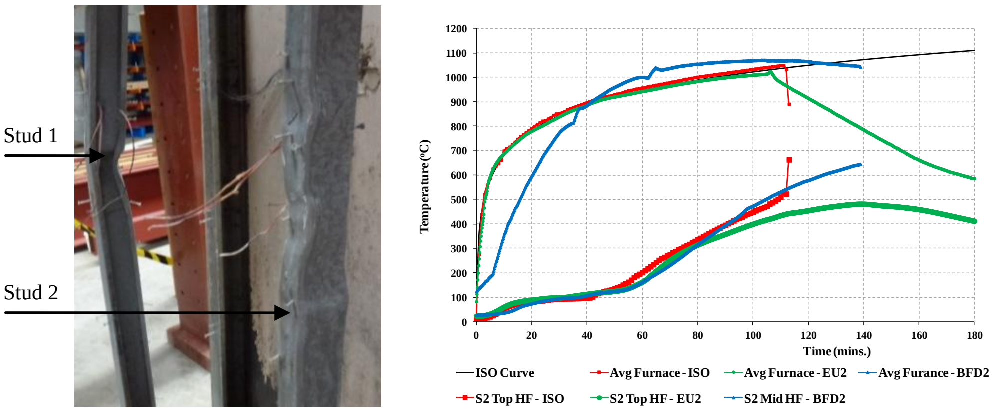
Table 3. Failure times and critical stud hot flange (HF) temperatures.

LSF Configuration		Fire Curve	Failure Time	Critical Max. Stud HF (^{o}C)	FEA Failure HF Temp (^{o}C)[18]
Double layers of Plasterboard (LR=0.2)	LSF1*	EU2-(0.03)	-	481	626
	LSF2	BFD2-(0.03)	139 mins	645	
	Kolarkar [17]	ISO Curve	111 mins	663	
Single layer of Plasterboard (LR=0.2)	LSF3	EU1-(0.08)	28 mins	561	611
	LSF4	BFD1-(0.08)	39 mins	630	
	Kolarkar [17]	ISO Curve	53 mins	550	
Composite panel (LR=0.4)	LSF5	BFD2-(0.03)	118 mins	527	510
	Gunalan [18]	ISO Curve	134 mins	523	

Note: * No Failure ; HF – Hot Flange; LR – Load Ratio

4.3.1 Test specimens LSF1 and LSF2 – Double layers of gypsum plasterboard

Test specimen LSF 1 was exposed to the furnace heat for a period of 180 minutes and did not fail under any failure criteria. Hence the furnace was turned off after 180 mints since the furnace temperature was in the fire decay phase and the maximum stud temperature is below 500^{o}C. During the test the furnace temperature was nearly 75 to 100^{o}C less than the target temperature profile of EU2-(0.03), which is identical to standard fire in the fire growth period up to 105 minutes and then followed the specified decay rate (see Figure 4b). The failure time of 111 minutes in the standard fire test (Table 3) indicates that EU2 curve with the decay phase was less severe than the standard test. The stud hot flange temperature reached 481^{o}C at 140th minute during the decay phase. As seen in Figure 4b, it was gradually increasing for 35 minutes even during the decay phase. Hence the studs could have failed during the decay period, if they had reached the critical hot flange temperature. If the intended higher EU2-(0.03) curve shown in Figure 1 was achieved, the stud failure might have occurred during the decay phase. Visual inspection of the tested specimen revealed that the face layer plasterboards (Pb1) has severely calcinated and partially collapsed in the middle. The second layer of plasterboards (Pb2) was partially calcinated but was intact and offering protection to the studs. The central stud (Stud 2) displayed some local buckling waves in the hot flange (HF) and web (W) near the top (0.5 H to 0.75 H). The ambient side plasterboards (Pb3 and Pb4) were in fairly good condition.



a.Failure pattern - LSF2 b. Average furnace & stud hot flange temperatures – LSF1, LSF2 & ISO.

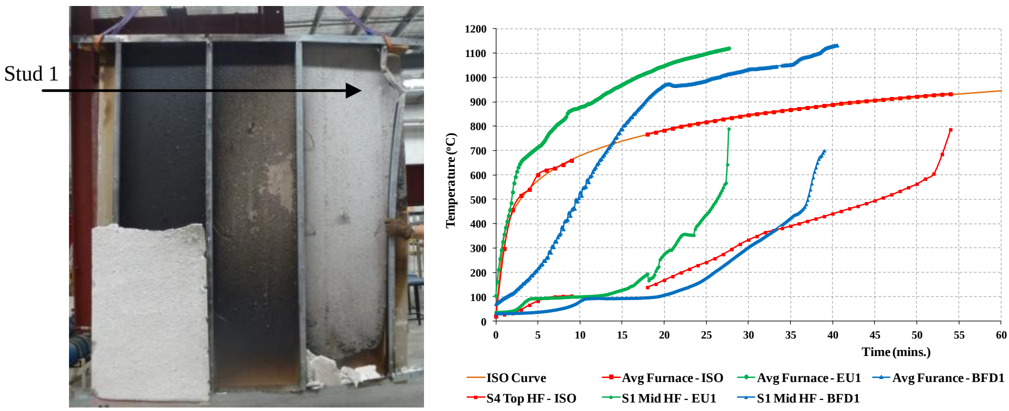
Figure 4. Test specimens LSF1 and LSF2

Test specimen LSF2 was exposed to the Barnett's 'BFD' curve for 139 minutes until it could no longer maintain the applied load. The initial lateral deflection was towards the furnace and it reversed after 120 min. After the test, the exposed plasterboard Pb1 had totally collapsed while a portion of Pb2 had also fallen off between Studs 1 and 2. The ambient side plasterboards were not calcinated although they had cracked horizontally at the plasterboard (Pb4) joint due to bending away from the furnace at failure (Figure 3b). In Studs 1 and 2 local buckling waves were observed near the mid-height of the wall. Test specimen LSF2 failed when the hot flange temperature reached 645^{o}C, which is similar to Kolarkar's [17] and Gunalan's [18] temperatures (663^{o}C) and (626^{o}C). Kolarkar's [17] test wall for standard fire curve failed by flexural buckling about the minor axis due to plasterboard fall-off, whereas LSF2 failed by flexural buckling about the major axis in Studs 1 and 2 with some local buckling (see Figure 4a).

4.3.2 Test specimens LSF3 and LSF4 – Single layer of gypsum plasterboard

Test specimen LSF3 structurally failed after 28 minutes of EU1-(0.08) fire curve exposure. Visual inspection after the test showed that the exposed plasterboard (Pb1) strip over Stud 1 had fallen off. This strip of plasterboard (150 x 2400 mm) was fixed only along one edge to Stud 1. The Stud 1 hot flange time-temperatures profile also confirmed this, where rapid temperatures rise of nearly 250^{o}C was noticeable within a minute as shown in Figure 5b. Due to the fall-off of this plasterboard strip, Stud 1 lost its lateral support and failed by minor axis flexural buckling as shown in Figure 5a. Local buckling waves were also noticeable in the hot flange of Stud 2. The ambient side temperatures were well below the insulation failure criteria temperature of 180^{o}C and were seen to be partially calcinated.

Test specimen LSF4 exposed to the 'BFD1-(0.08)' curve failed after 39 minutes. Similar to LSF3, the plasterboard strip attached to Stud 1 had fallen off, resulting in its minor axis flexural buckling.



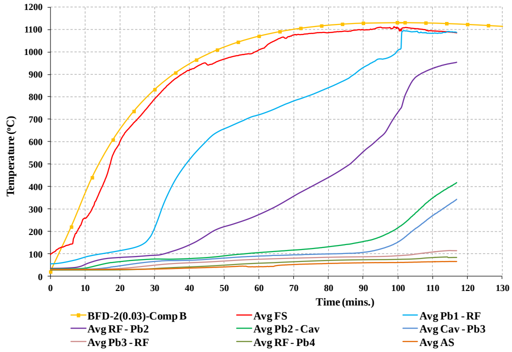
a. Failure pattern - LSF3. b. Avg furnace & stud hot flange temperatures – LSF3, LSF4 & ISO.

Figure 5. Test specimens LSF3 and LSF4.

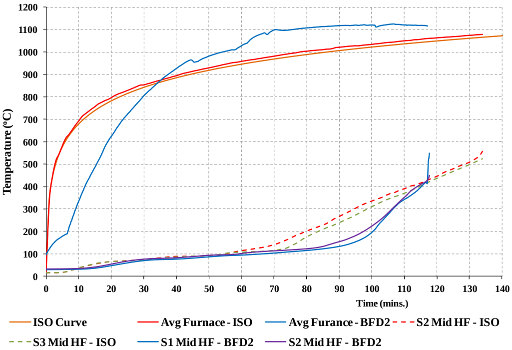
In all three tests, the failure occurred in the stud which had the vertical plasterboard strip (150 x 2400 mm) joint, and partial collapse of this plasterboard initiated the failure. This is clearly noticeable with a rapid temperature rise in the stud hot flange (HF) temperatures. Kolarkar's [17] standard fire test also showed the same failure mode. Figure 5b shows the stud hot flange temperatures at failure together with the average furnace temperature profiles. The stud failure temperature of LSF4 (630^{o}C) under the 'BFD' curve differs from those for the Eurocode parametric (561^{o}C) and standard curves (550^{o}C) (see Table 3). This is possibly due to the plasterboard fall-off at different temperatures resulting in a rapid temperature rise in the studs and causing them to fail earlier than in the standard fire test (Table 3). A rapid temperature rise can be seen in the stud hot flange under EU1 fire curve (see Figure 5b). In BFD1 and ISO curves the stud temperature rise is gradual compared to EU1 fire test due to its rapid temperature rise and higher temperatures than in other tests. This suggests that in BFD1 and ISO fire tests the plasterboard has partially collapsed, but a portion of the plasterboard was still intact and protected the stud further. Also the temperature that initiated the plasterboard fall-off was different in each test. In BFD1 fire test it was about 450°C, and for EU1 and ISO fire tests this temperature was about 550 and 600°C, respectively (Figure 5b). These values were taken as the starting point of the rapid stud hot flange temperature rise in Figure 5b. In the BFD1 fire test the furnace temperature was much higher than the standard curve and was also maintained at higher temperatures than in the case of other two fire curves. This higher heat flow might have caused the plasterboard to partially collapse at a lower temperature. This is because the plasterboard calcinates and shrinks rapidly at high temperatures and rapid temperature rise situations. Similar observation was made by Gerlich [19] where the plasterboard collapsed earlier during a severe fire than during an ISO fire test [1]. Gunalan's [18] FEA prediction of critical stud temperature (611°C) was based on the presence of lateral (plasterboard) support throughout the test. Therefore due to the early shrinkage and cracking of plasterboard, studs could fail by minor axis flexural buckling much earlier than predicted by FEA. Hence it appears that the plasterboard fall-off time depends on the rate of temperature rise, peak temperatures experienced and their duration.

4.3.3 Test specimen LSF5 – Composite panel (External Insulation)

Test specimen LSF5 failed structurally after 118 minutes exposure to the 'BFD2-(0.03)' curve. The initial lateral deflection was towards the furnace, and near failure it started to reverse its direction away from the furnace. The fire exposed plasterboard (Pb1) fell off after 100 minutes as seen in the temperature profile in Figure 6a. Also after 118 minutes the second layer (Pb2) attached to Studs 1 and 2 must have partially collapsed as seen in the stud hot flange temperature profile in Figure 6b. This has occurred earlier than in the standard fire tests. This caused Studs 1 and 2 to fail by minor axis buckling as no lateral restraints were available to prevent it. Hence this also indicates that the plasterboard fall-off depends on the type of fire curve used in the tests. Further experimental and numerical studies are in progress to fully investigate the behaviour of LSF wall panels under various realistic design fires.



a. Average plasterboard – LSF5.



b. Stud hot flange – LSF5 and ISO.

Figure 6. Experimental time-temperature profiles (F–Fire side, RF–Rock fibre & AS–Ambient side).

5 CONCLUSION

This paper has described an experimental study of the structural and thermal performances of load bearing LSF wall panels under realistic design fires. This study has shown that the plasterboard fall-off depends on the rate of temperature rise and the peak temperature during a fire test. This is important in the use of single plasterboard lined walls where the plasterboard fall-off will expose the load bearing wall studs and thus result in low fire resistance rating. Also it has been shown that the LSF wall studs could fail during the decay period if the stud temperatures reach the critical failure temperature. Further research is in progress to understand the behaviour of LSF wall panels under real design fires since the use of thermoplastics materials in modern buildings has increased the rate of temperature rise and peak temperatures during a building fire than indicated by the standard fire curve.

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